

THE EFFECT OF STRAW AND FERTILIZER ADDITIONS ON THE ORGANIC PHOSPHORUS IN THE SOIL

BY

HERMAN LEROY BRELAND

B.S., Mississippi State College, 1942

M.S., Purdue University, 1948

AN ABSTRACT OF A THESIS

SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS
FOR THE DEGREE OF DOCTOR OF PHILOSOPHY IN AGRONOMY
IN THE GRADUATE COLLEGE OF THE
UNIVERSITY OF ILLINOIS, 1952

URBANA, ILLINOIS
1952

THE EFFECT OF STRAW AND FERTILIZER ADDITIONS ON THE ORGANIC PHOSPHORUS IN THE SOIL

BY

HERMAN LEROY BRELAND

B.S., Mississippi State College, 1942
M.S., Purdue University, 1948

AN ABSTRACT OF A THESIS

SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS
FOR THE DEGREE OF DOCTOR OF PHILOSOPHY IN AGRONOMY
IN THE GRADUATE COLLEGE OF THE
UNIVERSITY OF ILLINOIS, 1952

URBANA, ILLINOIS
1952

ACKNOWLEDGMENT

The author is sincerely appreciative of the guidance and encouragement of Professor Roger H. Bray, under whose direction and help this work was done. He is also grateful to Professors S. W. Melsted and L. T. Kurtz for their invaluable advice and assistance with this work.

For the cooperation and kind assistance given by other members of the Soil Fertility Division and for the encouragement and sacrifices of his wife, Elsia, the author is grateful.

The author wishes to express his appreciation to the University of Illinois and the Herman Frasch Foundation for establishing the Assistantship which enabled him to study here.



THE EFFECT OF STRAW AND FERTILIZER ADDITIONS ON THE ORGANIC PHOSPHORUS IN THE SOIL

INTRODUCTION

It has long been recognized that significant proportions of the total soil phosphorus occur in organic combination. In the surface of many soils 30 to 85 per cent of the total phosphorus is organic. When phosphorus is added to the soil and is absorbed by the plant, it is partially converted into organic compounds of phosphorus. When the plant products are then returned to the soil, they provide a source of energy for the soil microflora which in turn synthesize organic compounds of phosphorus. On the basis of this evidence, it may be concluded that the organic phosphorus of soils is contained in compounds and derivatives of compounds synthesized by plants and microorganisms, biological fixation of phosphorus being the process by which these compounds are formed.

When organic matter is incorporated in soil rapid decomposition takes place, with bacteria and fungi playing an important part during the earlier stages. In the presence of soluble phosphate considerable synthesis of organic phosphorus may take place simultaneously. After the utilization of most of the easily decomposable energy material, such as sugars and hemicelluloses, decomposition by fungi becomes dominant. Under these conditions, a part of the organic phosphorus may be mineralized again. Thus, organic phosphorus in the soil may originate from the organic residues added to the soil, and also from synthesis by microorganisms.

The identity of the organic phosphorus compounds in soils is still somewhat obscure. However, the available evidence indicates that there are at least five types of organic phosphorus compounds which may be present in the soil at one time or another. These are phospholipids, sugar phosphates and related compounds, phosphoproteins, nucleic acids and phytin and their derivatives. All of the types may be readily attacked by the enzymes present in soil.

MATERIALS AND METHODS

Two soils were used to study the effect of soil treatments on the organic phosphorus levels in the soils. Topsoil from the Burwash plots and subsoil from the University Lysimeter bins were used for Greenhouse work. The soils were placed in two-gallon jars, then the treatments were applied and mixed thoroughly with the soil. No crop was grown. Experiments were also run on surface soil at the Burwash plots. This series of field plots received similar treatments which were plowed under. The field plots produced a crop each year.

The two soils varied widely in organic matter and phosphorus content. The topsoil used was a Flanagan silt loam containing about 60,800 pounds of organic carbon, 300 pounds of exchangeable potassium, and 130 pounds of phosphorus per acre. The subsoil also was a Flanagan silt loam taken 16 inches below the soil surface, and containing 10,460 pounds of organic carbon, 300 pounds of exchangeable potassium, and 69 pounds of phosphorus per acre.

The treatments consisted of adding organic matter in the form of wheat straw or alfalfa hay, and adding fertilizer at different rates and ratios to study their effect on the production of phosphorus in organic combination. The organic matter additions varied from 0 to 80 tons per acre. The basis for the fertility levels was that about 50 per cent of the straw is carbon, and that humus has a carbon-nitrogen ratio of about 10. Therefore, 10 tons of wheat straw would furnish about 10,000 pounds of organic carbon. In order to convert one-half of the plant carbon to humus carbon, assuming no loss, when the carbon-nitrogen ratio is 10, about 500 pounds of nitrogen would be required. Humus also contains a maximum of one per cent of phosphorus and sulfur, or carbon-phosphorus and carbon-sulfur ratios of about 50. Therefore, 10 tons of wheat straw at one-half fertility level would require 100 pounds of phosphorus and of sulfur to convert the plant carbon to humus carbon with a ratio of 50. The fertilizer additions were 0 (no fertilizer added), one-fourth, one-half and full fertility levels of nitrogen, phosphorus and sulfur.

The phosphorus was determined by the Bray and Kurtz method, using ammonium molybdate-hydrochloric acid and stannous chloride. The organic phosphorus was determined indirectly.

The organic carbon was determined by a modification of the Allison wet-digestion method.

Total and organic nitrogen were determined by the Kjeldahl method. The nitrate nitrogen determinations were made colorimetrically by use of Bray's nitrate powder. The ammonia nitrogen was determined by a modified procedure, using Nessler's reagent.

RESULTS AND DISCUSSION

Since phosphorus is only slightly mobile, and since the jars were not watered enough to cause a loss of phosphorus through leaching, all of the phosphorus added to the soil should have been recoverable. Therefore, as the treatments were increased the amounts of phosphorus found in the different fractions would be expected to increase. In general this was found to be true, with the acid-soluble, adsorbed and organic phosphorus values showing the largest increases. The acid-soluble and adsorbed phosphorus values had a tendency to increase with treatment. However, most of the organic phosphorus values for the topsoil were erratic. It may be that the phosphorus in the untreated topsoil was in equilibrium and that when fertilizers and straw were added they upset this equilibrium. This upset may have caused some of the organic phosphorus to be mineralized, and may possibly have made it go into a form that was not easily soluble. The fluctuations in the microbial population could conceivably have had some effect on the amount of phosphorus found in organic combination.

The subsoil samples showed increases in the organic phosphorus resulting from the increased treatments, even with the highest applications. This indicates that under these conditions the subsoil was more efficient than the topsoil in fixing phosphorus in organic combination. The subsurface

6- to 12-inch layer at the Burwash plots even showed increases in organic phosphorus due to the treatment of the surface layer. Due to unevenness of plowing, some of the straw and fertilizer was incorporated in the soil below the top six-inch sampling layer, causing an increase in the subsurface phosphorus. The breaking point in the production of organic phosphorus in the topsoil of the Greenhouse series seemed to be between 10 and 20 tons of straw at one-half fertility level for nitrogen and sulfur. At the Burwash plots the break came at approximately 15 tons of straw at full fertility level for nitrogen, phosphorus and sulfur.

At the higher applications of 80 tons of straw, the break in the organic phosphorus production for both the top and subsoil from the Greenhouse series seemed to occur at one-half fertility level with respect to nitrogen, phosphorus and sulfur. This was a very high straw application and there was only about 76 pounds of organic phosphorus produced, not nearly as much as was produced by the addition of nitrogen and sulfur at one-half fertility level, either with or without the 20 tons of straw. The heavy application of 60 tons of straw on the Burwash plots did not seem to increase the organic phosphorus over the smaller straw applications.

The application of nitrogen and sulfur, with or without straw at the 20-ton level, resulted in the largest organic phosphorus increases in the topsoil under greenhouse conditions. At Burwash plots the instances of highest organic phosphorus production occurred where no straw was added, with full nitrogen at the 40-ton straw level and full phosphorus at the 80-ton straw level; where no straw was added, with full phosphorus at the 80-ton straw level and with 498 pounds of potassium; and where 15 tons of straw was added, with full nitrogen and phosphorus levels.

When only one nutrient was added, with a constant straw level, to the surface soils, nitrogen or sulfur gave almost twice the amount of organic phosphorus as did phosphorus added alone. At the Burwash plots a combination of nitrogen and

phosphorus gave a very large increase in the organic phosphorus value. Nitrogen and sulfur gave a larger increase than phosphorus and sulfur, but not as large an increase as the nitrogen and phosphorus.

A considerable portion of the organic phosphorus on one series of the Burwash plots seemed to be mineralized and, since it was not recovered, it had apparently gone into a form of phosphorus that was not easily soluble.

CONCLUSIONS

Although the results are rather variable, the following trends are indicated:

1. The production of phosphorus in organic combination in the topsoil, which resulted from straw and fertilizer applications, seemed to increase up to about 15 tons of straw at from one-half to full fertility level with respect to nitrogen, phosphorus and sulfur. However, the topsoil in the Greenhouse series produced the most organic phosphorus, both with and without the straw application, at one-half fertility level with respect to nitrogen and sulfur.

2. The subsoil seemed to be more efficient in fixing phosphorus in organic combination than the topsoil. In every case there was an increase in the production of organic phosphorus when straw and fertilizer applications were made. Also, the subsurface 6- to 12-inch soil layer at the Burwash plots showed increases in organic phosphorus due to treatment of the surface soil.

3. There did not seem to be any advantage, or disadvantage, in using wheat straw as a mulch instead of turning it under, or of using a legume such as alfalfa hay instead of wheat straw to produce organic phosphorus.

4. The use of molybdenum did not have any measurable effect on organic phosphorus production; neither did the addition of high amounts of limestone.

5. The addition of 498 pounds of potassium along with the straw and other fertilizers gave some of the largest increases in organic phosphorus.

6. This study indicates that the production of phosphorus in organic combination may be increased on soils low in organic matter and available nutrients, and that extra potassium and sulfur may be necessary for maximum production of organic phosphorus. These possibilities warrant further investigation.

VITA

The author was born April 21, 1916, at Wiggins, Stone County, Mississippi. He received both his primary and secondary education at the Home Vocational High School, Wiggins, Mississippi. He graduated from high school in June 1935.

He entered Perkinston Junior College, Perkinston, Mississippi, and was graduated from that institution in June 1940. During the years 1937-38 he had to drop out of school and seek employment.

He enrolled in Mississippi State College, State College, Mississippi, in September 1940, and graduated from that institution in June 1942, receiving the Bachelor of Science Degree in General Agriculture.

He was employed by the United States Public Health Service at Gulfport, Mississippi, from June 1942 until January 1943, when he entered the Armed Service. He served in the Army from January 1943 until January 1946, with twenty-six months of this time being spent overseas.

He entered the Graduate School of Purdue University, Lafayette, Indiana, in June 1946 and received the Master of Science Degree in Agronomy in August 1948. He held a Fellowship sponsored by the American Potash Institute, Inc., from January 1947 until June 1948.

He entered the Graduate School of the University of Illinois in June 1948 as Special Research Assistant.

Publication: Potassium-Supplying Power of Several Indiana Soils. Soil Sci. 70:237-247, 1950.

